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THE BREEDING RANGE OF THE BARROW'S GOLDENEYE IN EASTERN NORTH AMERICA

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ABSTRACT.—The breeding range of Barrow's Goldeneye (*Bucephala islandica*) is largely restricted to northwestern North America, and little is known of the small population that winters in eastern Canada. Based on weak evidence, this eastern population was thought to nest mainly in northern Labrador. Our May 1990 to 1998 surveys identified a breeding area in the forest regions of the Quebec Laurentian Highlands. We observed Barrow's Goldeneyes on 137 lakes and 5 rivers, of which 95.2% were along the north shore of the St. Lawrence estuary and gulf. The species was found mainly on small lakes (≤ 10 ha) at greater than 500 m elevation. Most occupied lakes (96.5%) were within 100 km of the St. Lawrence River and 48.9% of them were headwater lakes. Four broods observed in 1998 represent the first eastern North American documentation of breeding. By means of satellite telemetry, 5 of 7 males captured on the wintering grounds were relocated on the north shore of the St. Lawrence River in May, 60–140 km inland from the estuary and gulf. Each male spent 34–50 days at its respective site, presumably with a mate. The north shore of the estuary and gulf may be the core breeding area for Barrow's Goldeneyes wintering along the St. Lawrence River. Received 29 March 1999, accepted 4 Sept. 1999.

The breeding range of Barrow's Goldeneye (*Bucephala islandica*) is largely restricted to northwestern North America, where more than 90% of the world population (ca 150,000–200,000) breeds from central Alaska to northern California (del Hoyo et al. 1992; Eadie et al., in press). Elsewhere, the species breeds in Iceland, where the spring population is estimated at 2000 birds and most individuals are sedentary (Scott and Rose 1996, Hagemeyer and Blair 1997). A single breeding

observation was recorded in Greenland in the nineteenth century; however, no observations have been reported for at least the last 30 years (Boertmann 1994). A few thousand Barrow's Goldeneyes are known to winter in northeastern North America, particularly in the St. Lawrence estuary, Quebec (Reed and Bourget 1977, Savard 1990), and a breeding population has recently been suspected in southern Quebec (Savard and Cormier 1995; Gauthier and Aubry 1996; Savard and Dupuis, in press). Many authors (e.g., Palmer 1976, Bellrose 1980, Godfrey 1986, del Hoyo et al. 1992, American Ornithologists' Union 1998) state that the species breeds in northern Labrador and southwestern Greenland but there is little documentation and some of the records have been disputed (Todd 1963). Apparently, as suggested by Scott and Rose (1996) and Hagemeyer and Blair (1997), the assumption is that the Barrow's Goldeneyes wintering in

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the St. Lawrence estuary and elsewhere in Atlantic Canada and the U.S. originate from these Arctic breeding areas.

We conducted surveys and tracked movements of Barrow's Goldeneyes using satellite telemetry because of growing concern about the vulnerability of the eastern population of this species (Gauthier and Aubry 1996; Savard and Robert 1997; Savard and Dupuis, in press) and because of the lack of information about their distribution. Here, we (1) document the first breeding records of the Barrow's Goldeneye in eastern North America, (2) describe the breeding distribution based on inland surveys and satellite telemetry, and (3) discuss the types of lakes where we found the species.

METHODS

Helicopter surveys.—Inland observations of Barrow's Goldeneyes were obtained from helicopter surveys conducted by the Black Duck Joint Venture (BDJV) of the North American Waterfowl Management Plan (Anonymous 1986, 1994). Each May 1990–1998, BDJV surveys in Quebec covered about 500,000 km² in the Boreal Shield and Atlantic Maritime ecozones (Wiken 1986) south of 51° 30' N. In 1990–1992, an original set of 83 100 km² (10 km × 10 km) quadrats systematically distributed over that area were annually surveyed. In 1993–1995, the number of quadrats was gradually decreased to 35 (50 in 1993, 43 in 1994, and 35 in 1995), all being randomly selected from the original set of 83. In 1996–1998, quadrat size was reduced to 25 km² (5 km × 5 km), but the number was increased to 156, half of them being randomly surveyed each year. Many 25 km² quadrats were located in the southwest quarter of the 83 original 100 km² quadrats to ensure continuity in the data set. Within each quadrat, the helicopter (Bell 206 L) flew over the margins of all aquatic habitats and all waterfowl were noted by three observers. Flight speed varied from 50 to 100 km/h, and altitude from 5 to 50 m, depending on the complexity of aquatic habitats and topography. All waterfowl observations were located on 1:50,000 topographic maps during the survey and later entered into georeferenced databases. Barrow's were distinguished from Common Goldeneyes (*Bucephala clangula*) by the distinctive, darker upperwing pattern of adult males (Tobish 1986) or, more rarely, by their facial crescent.

We conducted 2 additional helicopter surveys of Barrow's Goldeneyes in 1998. The first on 14–15 May to verify the presence inland of 2 males fitted with transmitters (see below) and to survey a few lakes located in the vicinity of these radio-tracked individuals. The second on 17 May was conducted over a 252 km² area 60 km inland northwest of Sept-Îles (66° 50' W, 51° 47' N), in which all 190 lakes were overflown in

the same way as for BDJV surveys. Lakes with Barrow's Goldeneye sightings were resurveyed in July to locate broods (Morneau 1998). Barrow's Goldeneye females were distinguished from Common Goldeneyes by their distinctive head and bill shapes and head color (Tobish 1986).

Ground surveys.—From 20 May to 4 June 1998, we surveyed Barrow's Goldeneyes on 34 accessible lakes in the controlled hunting zone ZEC Martin-Valin and 68 lakes in ZEC Chauvin. Both hunting zones are located about 60 km northwest of the mouth of the Saguenay River (69° 43' W, 48° 09' N). Each lake was surveyed at least once, using binoculars and a spotting scope. All lakes with Barrow's Goldeneyes were revisited at least once between 30 June and 8 July to locate broods.

Statistics.—Unless otherwise specified, all means are shown with their standard error. We used Microsoft Excel 7.0a for Windows 95 for statistical analysis.

Satellite telemetry.—We implanted satellite transmitters in 7 Barrow's Goldeneye drakes (Korschgen et al. 1996). We used Argos PTT-100 implant transmitters (Microwave Telemetry, Columbia, Maryland) that weighed about 51 g (4.6% or less of the body weight). Each transmitter had 4 lithium batteries, was L-shaped, measured about 57 mm long, 36 mm wide, and 15 mm deep on its deepest side (7.5 mm on the other), and had a 22 cm antenna made of Teflon-coated multi-strand stainless steel wire. We used a mobile surgical unit, including a portable anesthetic machine (Labvet, Dispomed Ltd., Joliette, Quebec) because we had to work in remote locations. We modified the procedure of Korschgen and coworkers (1996) for the surgery. Transmitters were gas sterilized (ethylene oxide at 38° C) and surgical instruments were autoclaved prior to field work. Each goldeneye was induced using a face mask (customized with a plastic cup) with a concentration of 3.5–4.0% isoflurane (Aerrane, Janssen, Mississauga, Ontario) delivered in oxygen. The bird was then intubated with a non-cuffed 3.5-mm endotracheal tube (Murphy's type, Portex, London, U.K.) to maintain anesthesia with a concentration of 2.5–3.0% isoflurane. A transparent surgical drape (Veterinary Specialty Products, Boca Raton, Florida) was used to cover the bird. The anesthetized bird was monitored with an ultrasonic Doppler flow detector (Medical Electronics Model 811-B, Parks, Aloha, Oregon) installed at the base of the tongue, and a respiration monitor (Tidal Volume Monitor, Medical Engineering & Development, Jackson, Michigan). Two veterinarians performed the procedure, one surgeon and one anesthetist, while a third person was available for technical help.

All birds ($n = 7$) were captured along the north shore of the St. Lawrence estuary, Quebec. We captured 3 adult males on 21–22 February 1998 at Baïdes-Rochers (69° 48' W, 47° 58' N) and 4 others on 7–10 April 1998 at Mistassini (67° 57' W, 49° 17' N). These two localities lie 170 km and 380 km downstream from Quebec City, respectively. Birds were attracted with Barrow's Goldeneye decoys ($n \geq 20$) and

captured using two 18 m mist nets (127 mm mesh size) set side by side over water, with three rafts similar to, but stronger than, the 'shallow-water system' described by Burns and coworkers (1995). Birds were transported and held in pierced plastic boxes (54 × 34 × 42 cm) in which paper strips were placed and changed regularly to avoid feather damage or contamination with droppings, or respiratory stress (from overwhelming dust or *Aspergillus* spores). Average time between capture and release after surgery was 5 h 42 min ± 36 min (range = 3 h 40 min–7 h 45 min). The surgical procedure, from incision to closure, was completed on average in 44 min ± 2 (range = 36–51). Birds were released to the wild on average 1 h 58 min ± 24 min (range = 1 h 15 min–4 h 1 min) after the end of anesthesia. To avoid long-term stress no duck was held overnight. Although we were not able to monitor each duck after its release, we observed no abnormal behavior attributable to the surgery.

Lake characteristics and distribution.—We used topographic maps (scale 1:50,000) to measure the area, perimeter, and elevation of each lake used by Barrow's Goldeneyes, and to determine whether the lake was a headwater lake. We calculated the shortest distance between each lake and the St. Lawrence River using digital maps (scale 1:2,500,000; Geomatics Canada).

Abundance map.—An abundance map of Barrow's Goldeneye pairs was constructed from the BDJV helicopter surveys to illustrate the species' breeding distribution in southern Quebec. To combine the 9 years of data, we first calculated annual densities of indicated pairs per 100 km² for all quadrats (either 25 km² or 100 km²). We then assigned to the coordinates of the center of all quadrats the maximum density of indicated pairs observed during any given year (each quadrat was surveyed from 1 to 7 years in 1990–1998). For each 25 km² quadrat that was part of a 100 km² quadrat, we used the center of the 25 km² quadrat and the maximum density irrespective of quadrat size, resulting in a total of 172 quadrats. Indicated pairs were estimated as follows: 1 or 2 birds = 1 pair, regardless of sex; otherwise = 0 pair (Bordage and Plante 1997). Because of the discrete nature of our data, we used the Inverse Distance Weighted interpolator (Environmental Systems Research Institute Inc., ArcView Spatial Analyst) based on a radius of 60 km to produce a continuous representation of the various density classes. Because quadrat centers were 50 km apart, the interpolation used as many as 4 neighboring quadrats.

RESULTS

Helicopter surveys.—From 1990 to 1998, 222 Barrow's Goldeneyes (129 males and 93 females, from a total of 118 observations) were identified during Black Duck Joint Venture surveys. Nearly all were located inland from the north shore of the St. Lawrence estuary and gulf on lakes ($n = 96$) and rivers ($n = 5$). Indicated pairs ($n = 108$) mostly con-

sisted of lone pairs ($n = 66$) and lone males ($n = 35$); all were observed between 10 May and 1 June. We located 2 of the males fitted with transmitters during surveys conducted on 14–15 May 1998; neither was accompanied by a female. A survey of the lakes in the vicinity of these 2 radio-tracked individuals yielded 17 other Barrow's Goldeneyes: 8 pairs and 1 lone male on 8 lakes. The survey conducted 60 km northwest of Sept-Îles in 1998 yielded 8 pairs and 1 lone male distributed on 6 lakes. During brood surveys on these same lakes, we observed 3 broods (13–14 July) and 1 lone female (16 July). Based on an incubation period of 30 days (Eadie et al., in press) and duckling age, we estimated that the 3 females with broods began incubation on 23 May, 2 June, and 10 June.

Ground surveys.—During spring surveys conducted north of the Saguenay River, we observed 36 Barrow's Goldeneyes on 23 lakes. Five lakes were in ZEC Martin-Valin and 18 were in ZEC Chauvin. Most observations were of lone pairs ($n = 12$) or lone males ($n = 9$). Subsequent surveys led to the discovery of 1 female accompanied by a brood on 2 July (photo in Bannon et al. 1998) and 7 lone females on 2–7 July. We estimated that the female with a brood began incubation on 30 May.

Satellite telemetry.—Beginning in the last week of April, 5 males moved 60–140 km [$\bar{x} = 84 \pm 34$ (SD)] inland along the north shore of the St. Lawrence estuary and gulf, between the mouth of the Saguenay River and Mingan (Fig. 1). They spent a minimum average of 44 days (± 6 ; range = 3–50) at their respective sites, presumably with their mates. The other 2 males stayed along the St. Lawrence River, where they were located until 5 June and 22 June 1998, respectively.

Lake characteristics and distribution.—Overall, we observed Barrow's Goldeneyes on 137 lakes and 5 rivers, 95.2% of which were along the north shore of the St. Lawrence estuary and gulf. Although birds were observed on lakes from 0.2 to 799.1 ha in size (26.4 ha ± 82.3; median = 5.3 ha; $n = 137$), most were found on small lakes with 45.6% and 69.9% of lakes occupied by Barrow's Goldeneyes being less than 5 ha and 10 ha, respectively. Lakes and rivers with Barrow's Goldeneyes were at a mean eleva-

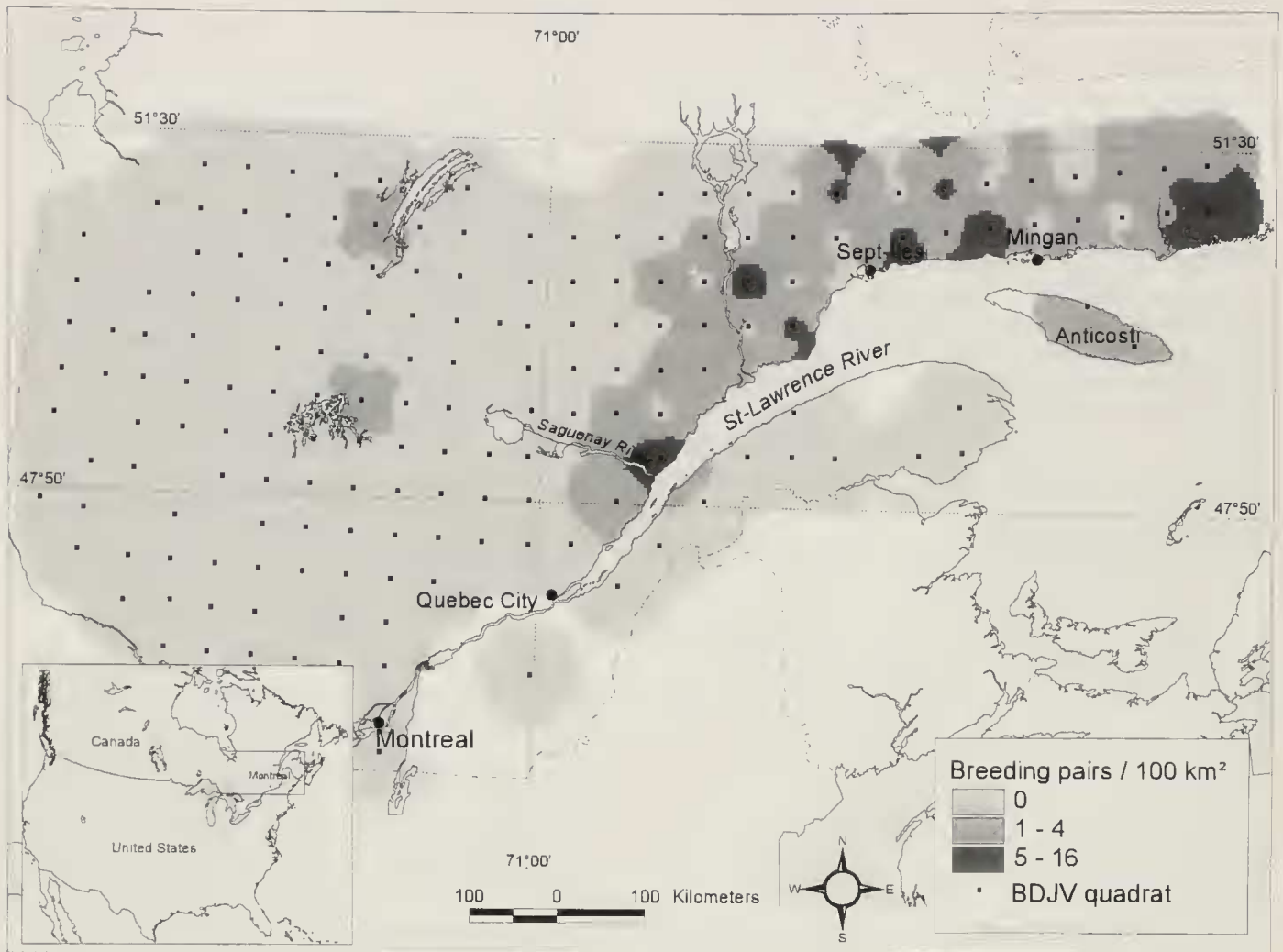


FIG. 1. Location of Black Duck Joint Venture (BDJV) survey quadrats and estimated breeding densities of Barrow's Goldeneyes in southern Quebec.

tion of 489 m (± 187 ; median = 518 m; range = 100–792; $n = 142$), with 54.2% and 29.6% of them above 500 m and 600 m, respectively. Almost half (48.9%) were headwater lakes. Few Barrow's Goldeneyes were located far from the St. Lawrence River; nearly all occupied lakes and rivers (96.5%) were within 100 km of it ($70.1 \text{ km} \pm 53$; range = 13–430; $n = 142$).

Abundance map.—Indicated breeding pairs were observed on 27 of 172 of BDJV quadrats, 25 of these were north of the St. Lawrence River (Fig. 1). We delineated a 'core breeding area' north of $47^{\circ} 50'$ N and east of 71° W where we observed indicated pairs in 25 of 47 of the quadrats surveyed. Only 2 indicated breeding pairs were recorded outside this area. The highest breeding pair densities were recorded on the Laurentian Highlands in quadrats closest to the St. Lawrence River.

DISCUSSION

Our observations of 4 different broods constitute the first documented breeding records of Barrow's Goldeneyes in eastern North America. The difficulty of positively identifying females and young goldeneyes in the field (Tobish 1986) and the remote nesting areas occupied by the species have certainly been responsible for the delay in establishing definite breeding records for this region. Given that the species breeds within 100 km of the St. Lawrence River, we think that some of the historical breeding records of the Barrow's Goldeneye on the north shore of the St. Lawrence disputed by Todd (1963) could well be valid. This could be the case for Merriam's (1881) and Salvadori's (1895) records. The 2 lone females shot by Todd himself on the St. Margaret River on 10 and 30 June 1917 (Todd 1963) could also have been nesting individuals based on the time they were collected (see

also Comeau 1909). Other unsubstantiated breeding records have been reported in eastern North America. These include a 'probable' female Barrow's Goldeneye with 9 young reported in the Torrent River watershed area of Newfoundland in 1993 (Daury and Bateman 1996), and a nest collected in 1886 on the coast of Newfoundland originally identified as a Barrow's Goldeneye nest by its collector (Western Foundation of Vertebrate Zoology, #90022). However, according to egg measurements (R. Corado, pers. comm.), and knowing the difficulty of distinguishing between Barrow's and Common goldeneye females (especially during the nineteenth century), we think the latter record could have been a Common Goldeneye nest.

Based on our satellite tracking, at least some of the Barrow's Goldeneyes wintering along the St. Lawrence River breed along the north shore of the estuary and gulf. In fact, the large numbers of pairs and lone males we detected in aerial and ground surveys indicate that this area may be the core breeding area for the 2000–4000 (Reed and Bourget 1977; Savard and Dupuis, in press) Barrow's Goldeneyes wintering along the St. Lawrence. Because of this, we question the assumption that Barrow's Goldeneyes wintering in Quebec and elsewhere in Atlantic Canada and the U.S. originate from Arctic breeding areas (see Scott and Rose 1996, Hagemeyer and Blair 1997). In our view, the north shore inland from the St. Lawrence estuary and gulf represents a sizable breeding area that can account for most, if not all, of the Barrow's Goldeneyes wintering in Quebec. Because of this, we also believe that the status of the Barrow's Goldeneye in northern (Arctic) Labrador and Quebec requires further investigation. According to Palmer (1976), the species breeds near or along the upper half of the Labrador coast and is probably an occasional nester inland at least in northern Ungava. Todd (1963) reported various records of adults and young, and mentioned L. M. Tuck as having collected specimens, including juveniles, at various points along the Labrador coast. 'Probable' Barrow's Goldeneye eggs were also collected in 1887 from a nest found on the coast of Labrador (Western Foundation of Vertebrate Zoology, #123700; R. Corado, pers. comm.). The species may also breed in the Hudson Bay area

(Todd 1963, Gauthier and Aubry 1996). Nevertheless, it is quite possible that some of the northern observations were of birds migrating to their molting sites because Barrow's Goldeneyes molt in Hudson Bay, Ungava Bay, and in some fjords of northern Labrador (C.W.S., unpubl. data). Obviously, the breeding of Barrow's Goldeneyes in treeless Arctic environments of eastern North America needs to be better documented.

Most Barrow's Goldeneyes were observed east of the Saguenay River and north of the St. Lawrence estuary and gulf, with the highest densities in the southern portion of the Laurentian Highlands. Generally, birds were found in the Boreal ecoclimatic province of Quebec, in the black spruce (*Picea mariana*)-feather moss (Hypnaceae) and balsam fir (*Abies balsamea*)-white birch (*Betula papyrifera*) forest regions (sensu Gauthier and Aubry 1996). Although no survey quadrats were located within 30 km of the St. Lawrence River, we suspect that Barrow's Goldeneyes are unlikely to breed there. This area corresponds to the East St. Lawrence lowlands (sensu Gauthier and Aubry 1996), is at sea level, and contrasts markedly with the high elevation habitat where we found most pairs of Barrow's Goldeneyes. Breeding pairs observed west of 71° W and on Anticosti Island were all single year observations indicating that these individuals may have been migrating. Indeed, despite extensive field studies on Anticosti Island (Ouellet 1969, Gauthier and Aubry 1996), no breeding Barrow's Goldeneye has been confirmed.

Our results clearly indicate that the respective breeding ranges of Barrow's and Common goldeneyes (Gauthier and Aubry 1996) are not mutually complementary in eastern North America as suggested by Todd (1963). He associated the former with the treeless areas of the Arctic and the latter with forested areas. On the contrary, our study indicates that these two species have sympatric distributions, at least in some parts of the boreal forest of eastern Quebec. There might be a segregation of the two species based on elevation. In southern Quebec, the mean elevation increases east of the Saguenay River (Ecological Stratification Working Group 1995), which corresponds to the western limit of the core breeding distribution of Barrow's Goldeneyes.

In fact, it is clear that most Barrow's Goldeneyes are associated with high elevation lakes and are rarely found on low elevation lakes. The Common Goldeneye commonly occurs on low elevation lakes (D.B., pers. obs.), but its abundance on high elevation lakes remains to be verified. Such segregation of the two species has been documented in the Columbia Valley, British Columbia (Savard 1984). There, Barrow's Goldeneyes were restricted to the alkaline ponds of the plateaus, whereas Common Goldeneyes were most numerous on the freshwater valley ponds. Definitely, a comparative study of the two species of goldeneyes is needed in eastern North America.

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